Optimization of ground plane antenna gain by increasing the inductance of loading coil based on silver material

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Article Info

ABSTRACT

To overcome the attenuation due to signal distortion in the telex model antenna transmitter, the copper and silver coil loading materials for gain have been tested. The parameters include standing wave ratio (SWR) value≈1, the antenna impedance (ZL), return loss (RL), reflection coefficient (ρ) which measured the bandwidth (BW) and quality factor (Q). In this experiment a telex model ground antenna is used, a coaxial feeder cable with 50 Ω and an operating frequency of 144.280 MHz was used. The feeder cable is tuned to approximate pure resistive with minimum impedance to reach maximum resonance frequency. The field strength effective radiated power (ERP) is measure based on 4 measurement points which has different distances within 100 km areas. The results show that the antenna based on copper loading coil (CLC) has a bandwidth is BW=5.166 MHz and Q=27.929, moreover, the silver loading coil (SLC) antenna the bandwidth is BW=4.500 MHz and Q=32.062. Therefore, SLC material could provide a good reduction in attenuation of signal distortion when signal radiation occurs from the antenna to the air.

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1. INTRODUCTION

The antenna is a transitional device between the transmission line and free space and vice versa. Antennas are made of metal in the form of rods or wires and function to transmit or receive radio waves [1]–[6]. Antennas have various types of circuits and models, when an antenna is used it has two uses, namely emitting electromagnetic wave signals and receiving electromagnetic wave signals. The guide wave travels along the transmission line, then is radiated into a free space waves [7]–[9]. To overcome attenuation due to long distances and large signal distortion, loading coils have been used for decades [10]–[14].

In a radio telecommunication system, this part is very important and requires more handling because many factors can affect the level of reception and transmission, including the voltage standing wave ratio (SWR) value, the type/model of the antenna, the physical dimensions of the antenna, the effectiveness or antenna gain, and directives [16], [17]. Good antenna transmission is the radio output power has minimal power reach the transmission distance as far as possible so that it will save electricity consumption besides that the radio device will also last longer [2], [5]. Loading coils are inductors that are inserted into an electronic circuit to increase their inductance which is used to prevent signal distortion in long-distance telegraph transmission cables. It is also used in radio antennas, or between an antenna and its feeder, to shorten the resonance of an antenna electrically at its operating frequency [15]. Ground plane antenna [18]–[22], telex model includes this

type of antenna which is widely used in radio telecommunications in the amateur radio community, the police, the Indonesian red cross, disaster management agencies, and volunteers [22]–[25].

The working frequency is usually in the high frequency (HF), very high frequency (VHF) and ultra high frequency (UHF) bands. This antenna construction consists of 2 rods of 5/8 λ size between the loading coil and 2 groups of multilevel radial arrangement (pseudo ground) each consisting of 4 rods measuring 1/4 λ [26]–[28]. The rod material usually uses aluminum and for loading coil using copper wire. Loading coil with a DC ground system is attached to a connector as the power input point of the transmitter amplifier via the coaxial feeder cable[29], [30].

2.   TELEX ANTENNA GROUND PLANE SYSTEM MODEL

The development of telex antennas has been carried out by several researchers, among them are [3]–[5], [11], [12], [16], [31]–[33]. Several studies related to antenna materials have been carried out by [34], [35], by making a 3-element yagi antenna using various materials such as iron, brass, copper and aluminum in order to get the most basic materials for radio wave transmission [36]–[39]. However, aluminum and copper produce a smaller SWR value than other materials and for the manufacturing process aluminum is easier to shape and lighter in weight [40]–[42].

Several studies on ground plane antennas have also been carried out, including [20], [25], [43], [44], in their research a 2×5/8 (λ) ground plane antenna using copper coil loading materials and radial ground has been designed and built amounting to 8 pieces [45]–[47]. This antenna is very suitable for areas and hilly conditions or areas with many buildings and is stronger than antennas with 1×1/4 λ ground plane, or 1×1 / 8λ vertical antennas [48]–[50]. Researchers [21], [51]-[56] has conducted research by making a ground plane antenna 3×5/8 λ which is based on a telex antenna and produces a greater beam strength but its physical size is much longer than a regular telex antenna.

Research conducted by [51] states that the effect of loading coil in the antenna can reduce the damping value up to 0.052 nepper, so that it has a small distortion value by increasing the inductance value of the loading coil. However, the value of the input voltage when passing through the copper cable is not dampened but it is increasingly strengthened by the copper cable, thus increasing the inductance value on the loading coil and the gain is also greater.

The greater the number of loading coils in the antenna, the greater the effect on the attenuation of copper cables. The problem is that this copper cable cooper loading coils (CLC) has a very high level of attenuation, so that it affects the gain obtained. Although it can be reduced by increasing the number of loading coils, but this method is very ineffective and affects the inductance and impedance of the antenna.

To overcome this, a study of the loading coil material needs to be carried out to reduce the damping level and reduce the distortion value in the transmitter. In this works, the type of silver material silver loading coils (SLC) is used to determine the difference in damping and distortion characteristics, especially referring to the parameters of the frequency bandwidth, quality factor, transmission distance from the antenna with reference to the number of turns, wire size, spacing between windings and all antenna rod sizes are the same including the value of the SWR.

3.   ARCHITECTURE OF ANTENNA GAIN IMPROVEMENT MODEL

To find the optimal effect of these materials, Figure 1 illustrates a model architecture for increased ground plane antenna gain. Based on the SWR measurement, the impedance value (ZL), the reflection coefficient (Γ), and return loss (RL) can be calculated. The measurement of the frequency characteristics is obtained by observing the SWR value graph which is 1.5 at two frequencies, namely the lower limit frequency (f_L) and the upper limit frequency (f_H).

The difference between f_H and f_L is the bandwidth (BW) of the antenna, and by directly comparing the BW with the operating frequency (f_O). The value of the quality factor (Q) is obtained. Measurement of the received field strength was carried out by 4 stations with different distances around 100 km and positions in the four corners around the antenna which functioned as a transmitter.

Antenna gain is obtained by calculating based on effective radiated power (ERP) measurements at each station and adding them up. The measurement performance of the parameters is carried out by experimenting in the field. And calculated using a vector network analyzer that can measure the output parameters directly both in display and in file form.
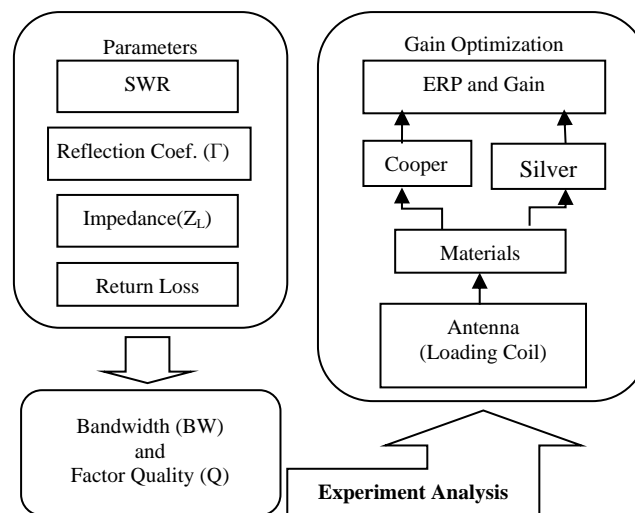
Figure 1. Experimental analysis of architecture of antenna gain enhancement model using loading coils based on cooper and silver materials

3.1. Loading coils

An antenna loading coil is an antenna loading coil that is an inductor that is placed in series on the antenna element to reduce the resonance frequency of the antenna and for impedance adjustment [57]. To maintain the resonator at the specific frequency, monopole and dipole antennas are designed. The physical antenna has one quarter of the wavelength of the radio frequency (RF) to resonated. The antenna has acted electrically as a pure resintance which absorbing all the signal power from the transmitter. The coil design used is as shown in Figure 2.
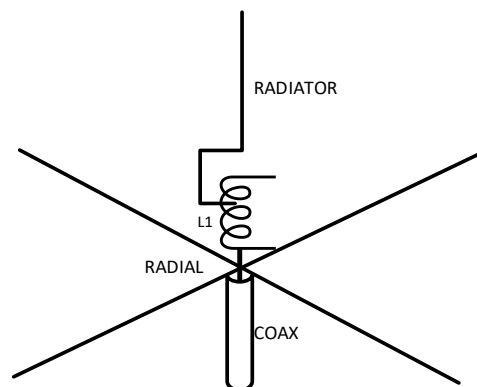

Figure 2. Loading coil [57]

3.2. Antenna parameters

Several antenna parameters need to be considered in determining the type of antenna, including impedance, SWR, return loss, bandwidth, quality factor, and gain. The SWR is the ratio among the reflected signal and the the transmitted voltage signal. Whereas, the loss of the signal strength due to the voltage reflection coefficient is the return loss. Moreover, effective isotropic radiated power is a calculation used to estimate the radiated output power of an isotropic. This function takes into account transmitter output power, cable loss, and antenna gain. Each antenna generally has the same characteristics as a transmitter and receiver.

3.2.1. Antenna impedance

At a terminal, the antenna impedance can be defined as the ratio between the voltage to the current at that terminal, [55], [56], [58]-[60]. Impedance is important in the design of the antenna because the antenna

itself actually serves as adjusting the antenna impedance with the impedance of the channel. This adjustment needs to be done so that maximum power transfer from the source occurs by the size, physical construction and materials and working frequency of the antenna.

$$Z_T = \frac{(V)}{(I)} \tag{1}$$

3.2.2. Voltage standing wave ratio (SWR)

On a transmission line there are two components of the voltage wave, namely the transmitted voltage (Vo +) and the reflected voltage (Vo-). The ratio between the reflected and transmitted voltage is known as the voltage reflection coefficient (Γ), which is shown in (2). Z_1 is the load impedance and Zo is the lossless line impedance. The stress reflection coefficient (Γ) has a complex value, which represents the magnitude and the reflection phase, [59] [60].

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_1 - Z_0}{Z_1 + Z_0} \tag{2}$$

To find SWR in (3) is used as follows [59].

$$SWR = \frac{V|max\,|}{V|min\,|} = \frac{1 + \Gamma}{1 - \Gamma} \tag{3}$$

The best conditions are when the SWR is 1, which means there is no reflection when the line is in a state of perfect matching. However, this condition is in practice difficult to obtain. Therefore, the standard safe SWR value for antenna fabrication is SWR <1.5.

3.2.3. Return loss

Return losses or reflection loss is the loss of signal strength due to the reflection behind the resulting discontinuity in a transmission line tele-communication both conventional and fiber optic. This state is usually expressed as a ratio in decibels (dB), where the return losses are given by the following equation [55], [60].

$$RL\,(dB) = 1\log\frac{P_2}{P_T} \text{ or } RL(dB) = 10\,log - 20\,log\,|\Gamma| \tag{4}$$

Where RL (dB) is behind the loss in dB, P_i is the signal strength that occurs and P_r is high refrection. The more signal strength lost behind a piece of equipment, the better the equipment.

3.2.4. Bandwidth (BW)

The bandwidth of an antenna is the working frequency area of the antenna which is limited by a certain SWR. Usually the bandwidth is limited to SWR ≤ 2.0. In a broadband antenna, bandwidth is the difference between the upper frequency (f_H) with a lower frequency (f_L) [61]:

$$BW = f_H - f_L \tag{5}$$

3.2.5. Quality factor (Q)

Is a measure of the selectivity of the resonator circuit where the resonator circuit is a Band Pass Filter (BPF) filter circuit with a narrow bandwidth. The larger the Q value, the bandwidth will be more and more narrow [61]:

$$Q \equiv 2\pi \frac{The\ maximum\ energy\ stored}{energy\ dissipated\ each\ vibration}\Big/cycle \tag{6}$$

impedance can reach the maximum or minimum value for their resonance, a condition in which the circuit is excited at its natural frequency and the frequency that causes the condition occurs is called the resonant frequency (f_o). The quality factor can also be expressed as the ratio between the resonance frequency of the bandwidth [61].

$$Q = \frac{f_o}{BW} \tag{7}$$

3.2.6. Field strength: field strength

Or also known as field intensity, generally have a strong sense as a field of a magnetic or an electric wave electromagnetic from a given point. In particular field strength which has magnitude of of dBμV/m can be defined as the field strength received by the receiving antenna of electricity electromagnetic energy emitted by radio transmitters on a particular frequency. At the point of measuring the field strength, the field strength meter will detect some of the strength of the electromagnetic wave energy (U) in dBμV/m [60].

3.2.7. Gain and efective radiated power (ERP) antenna

Antennas that have the nature of guidance (including dipole) is said to have reinforcement and measuring the gains made by comparing it to the isotropic antenna. Isotropic antenna is assumed to have no reinforcement because the radiation in all directions. Dipole antenna has a ± 2.1 dBi effectiveness against isotropic antenna. Effectiveness is always interpreted as a comparison against a reference. Effectiveness antenna G is expressed by dB, since dB is very practical in measuring the ratio of power [60]. ERP calculations start with the transmitter power output transmiter power output (TPO). (It is assumed as the output of the power amplification stage end if an external power amplifier is used) Then the system gain of the overall antenna system includes an antenna, transmission line, and all the components of the transmission line is applied to the TPO to calculate the output power of the entire station, as shown in (8) [57].

$$System\ Gain\ =\ Transmission\ Line\ Loss - Transmission\ Loss\ Component\ +\ Antenna\ Gain$$
$$ERP\ =\ TPO\ \times\ System\ Gain \tag{8}$$
$$ERP\ (dBm) = TPO\ (dBm) + System\ Gain\ (dB)$$

Where TPO is transmiter power output in this experiment, a vector network analyzer antenna used to measure all these parameters.

4.   PROPOSED TESTING SYSTEM MODEL

4.1. Measurements resonance feeder cable

To tune the feeder cable that resonates at a frequency of 144.28 MHz, a dummy load is required. In order for the power emitted from the transmitter to produce optimal power, the output impedance of the final stage power amplifier must be the same as the transmission line impedance and the antenna impedance. In this experiment a cable cutting is done little by little to get value of SWR≈1. Model testing can be seen in Figure 3.

4.2. Characteristics frequency antenna measurement

The frequency characteristics or may be called the width of the frequency band antenna tested with SWR meter or using antenna analyzer. How the tests performed is an antenna used for transmitting from the lowest frequency to the highest frequency with a maximum of 1.5 VSWR meter (generally 2.0). How to measure the antenna frequency characteristics can be seen in Figure 4.

4.3. ERP and antenna gain measurement

A transmitter will emit an electric field through the antenna, and the measuring instrument is installed in a location around the antenna at different distances. Measurements using a field strength meter or signal meter that is already available on the radio tranciever. Through the ERP value calculation will be obtained at each station location. While the gain is calculated based on the value of the ERP. The test model is seen in Figure 5.
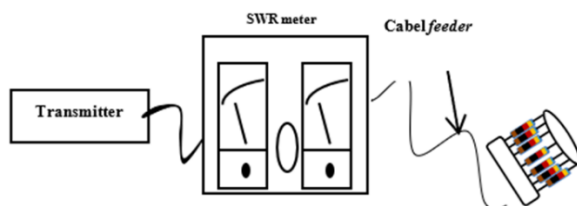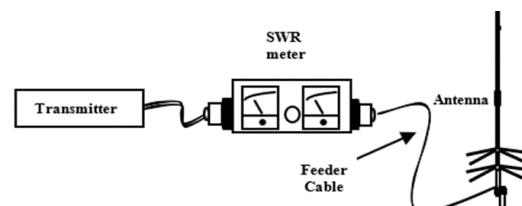
Figure 3. Resonance feeder cable model

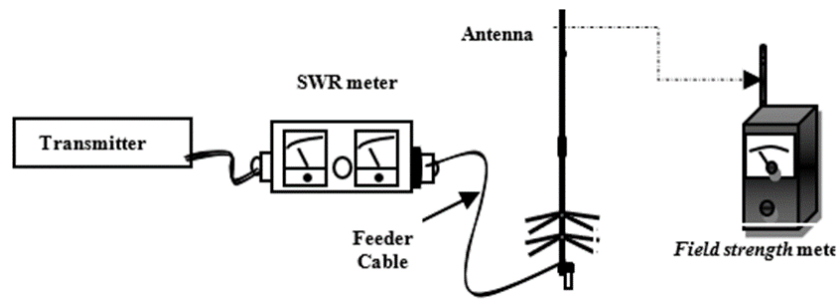Figure 4. Characteristics frequency antenna measurement model

Figure 5. Model antenna field strength testing

5. RESULTS AND ANALYSIS

Antenna system test results obtained by performing the above procedure is initiated by adjusting the impedance between the coaxial cable as a feeder with a dummy load, then adjust the antenna impedance with the feeder cable to get SWR≈1. In the test experiment in this study, the 1st antenna is expressed with copper material CLC and the 2nd antenna represented by the SLC. The following are the results of the measurements taken.

5.1. Resonance tuning of the feeder cable

This step is taken to get the cable length according to the desired working frequency, in this study it is 144,280 MHz. In practice, this step is needed so that the cable requirements are in accordance with the planned support pile height in addition to the return losses in the channel as large as possible. By using antenna analyzer measurement results obtained in accordance Figure 6.
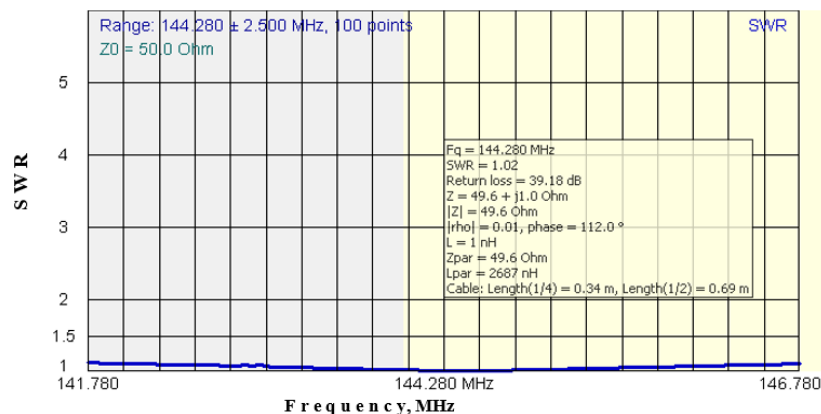

Figure 6. The measurement results feeder cable

The cable used is KSR 300 king signal having a characteristic impedance of 50Ω and a velocity factor of 0.66 (66%). Results obtained cable tuning cable length 10,24m, at a frequency of 144.280 MHz SWR obtained value=1.02, -39.18 dB return loss, impedance-j0,1 Z=49.6 Ω and cable length of 1/2λ is 0, 69m. The desired frequency is 144.280 MHz, in calculation of lengths obtained are as follows:

$$\lambda 0 = 3x106 \; Hz/144,28x106 = 2,07929026 \; meter \; (on \; air)$$

whereas if it propagates in the media, the propagation speed changes more slowly so that the velocity factor (v_f) data is needed to calculate the wavelength of the feeder cable used, so that the wavelength changes as follows:

$$\lambda = vfx\lambda_0 = 0,66x2,07929026 = 1,37233158 \; meter$$

$$1/2 \; \lambda = 1,37233158/2 = 0,6861657887 \; meter$$

the required cable length is a multiple of 1/2 λ because the SWR value will repeat every 1/2 λ [62]. This study used a multiplier 15 to obtain 15×0,6861657887meter=10.2924868305 meter.

5.2. Measurement of antenna frequency characteristics

The results of tuning and measuring the frequency response to the SWR value and the return loss of the antenna in the frequency range 119,280 - 169,280 MHz can be seen in Figure 7 to Figure 12. At the desired frequency, 144,280 MHz, the SWR value of each antenna is obtained with a copper loading coil (1st antenna/ CLC) is 1: 1,11 and the silver material (2nd antenna/ SLC) is 1: 1,12.

Especially for antenna 1, the antenna parameter data is obtained according to Figure 7 as follows. At the desired frequency, which is 144.280 MHz, the impedance value is Z=45.1+j0.4 Ω, |Z|=45.1 Ω, reflection coefficient |Γ|=0.05, return loss RL=25.66 dB. From this data it could be calculated and matched with the measurement results including the SWR value, reflection coefficient value |Γ|, return loss (RL), frequency bandwidth (BW) and quality factor (Q) of the antenna.
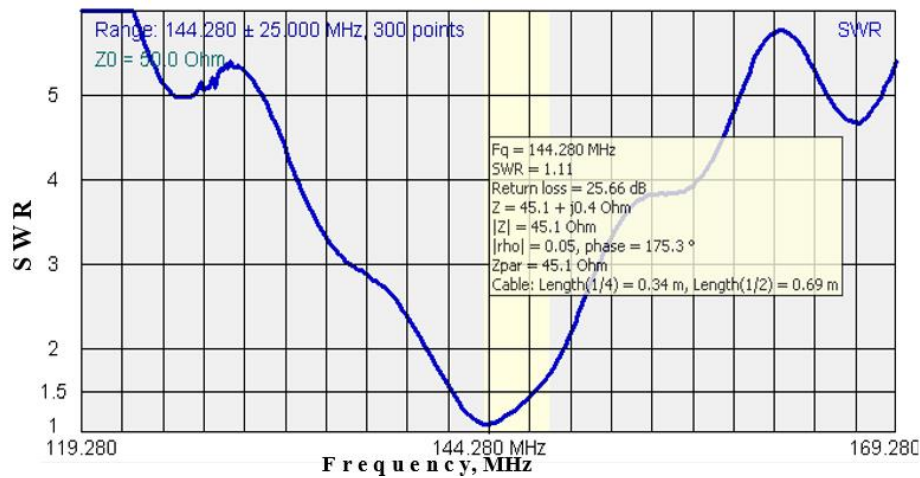

Figure 7. Frequency characteristics of cooper loading coils (CLC) on antenna 1

Based on the impedance of the antenna 1 is calculated how much the reflection coefficient and its SWR value based on the (2)-(4) that as shown in Table 1.

$$Z = 45,1 + j0.4 \ \Omega$$

$$|Z| = \sqrt{45,1^2 + 0,4^2} = \sqrt{2034,01 + 0,16} = \sqrt{2034,17} = 45,1018 \ \Omega$$

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_1 - Z_0}{Z_1 + Z_0} = \frac{50 - 45,1018}{50 + 45,1018} = \frac{4,8982}{95.1018} = 0,05150481$$

$$SWR = \frac{V|max\ |}{V|min\ |} = \frac{1 + \Gamma}{1 - \Gamma} = \frac{1 + 0,5150481}{1 - 0,5150481} = \frac{0,05150481}{0,94849519} = 1,1086032$$

$$RL = -20 \ log|\Gamma| = -20 \ log \ 0,05150481 = -20 * -1,2881522 = 25,763044 \ dB$$

The whole parameters measurements are shown in Table I as follows:

Table 1. Value parameter measurement comparison between CLC and SLC

Parameters	CLC (Antenna 1)	SLC (Antenna 2)
Z	45,1+j0.4 Ω	44,6+j0.5 Ω
|Z|	45,1018 Ω	44,6028 Ω
|Γ|	0,05150481	0,05705117
SWR	1,1086032	1,12100587
RL	25,763044 db	24,8747 db

To get optimal results, then adjusting the size of the rod antenna SWR be set to produce the smallest possible value. Antenna measurement obtained from a minimum value for the antenna SWR CLC was 1.11 and for antenna SLC is 1.12. Due to the size of the rod antenna setting can not be in tunning for approaching SWR = 1 on the same working frequency of 144.28 MHz. Thus, the consequences for the value - the value of Z, lZl, | Γ | and RL is better than SLC antenna. It also means that power is going (forward) to the CLC will be greater than those to the SLC and the reflected power (reverse) SLC larger. However, from the measurement when used for radiating or operated actually obtained value larger ERP despite SLC SLC power is going to be smaller than the antenna 1. This indicates that the SLC is better (higher efficiency) than CLC using copper.
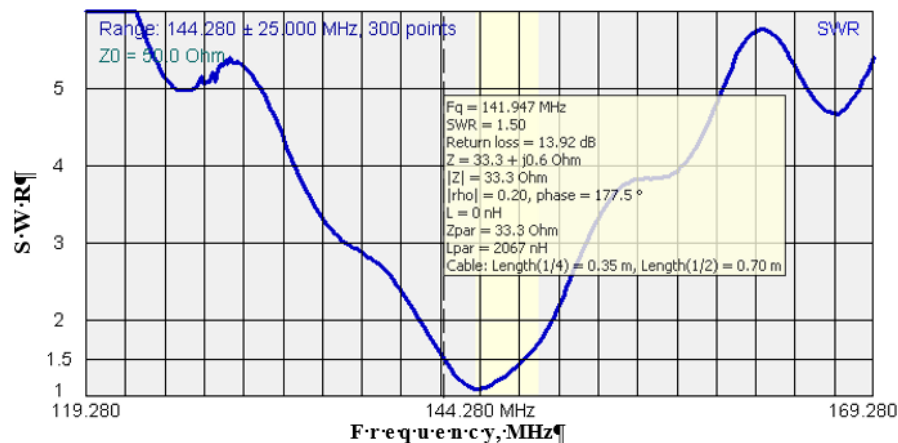

Figure 8. The lower limit frequency of the 1st antenna

Figure 8 shows the lower frequency limit of the antenna 1 where the value of SWR=1: 1.50 falls on frequency 141.947 MHz, whereas Fig 9 shows the frequency 147.113 MHz at SWR value=1: 1.48 (because the cursor can not be precise in SWR=1: 1,50). From both these frequencies can be calculated bandwidth (BW) as the frequency response characteristics of the antenna 1 and also the value of the quality factor. Based on the (5) is obtained.

$$BW = 147,113 - 141,947 = 5,166\ MHz$$

By using (7) the value of the quality factor Q is calculated as follows:

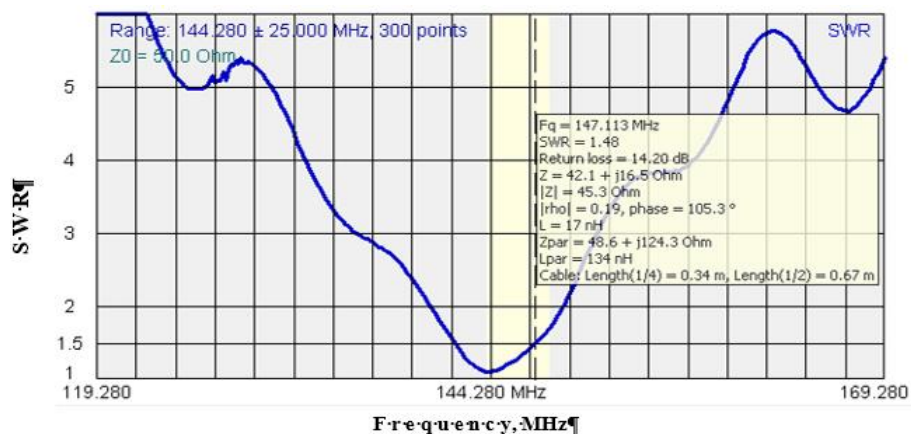$$Q = \frac{f_o}{BW} = \frac{144,280\ MHz}{5,166\ MHz} = 27,929$$

Figure 9. The upper limit frequency of the 1st antenna

Figure 10 is the result of the measurement antenna 2 (SLC), antenna parameter data obtained as follows; At a desired frequency is 144.280 MHz impedance value Z=44.6+j0.5 Ω, |Z|=44.6Ω, the reflection coefficient |Γ|=0.06, return loss RL=24.82dB.
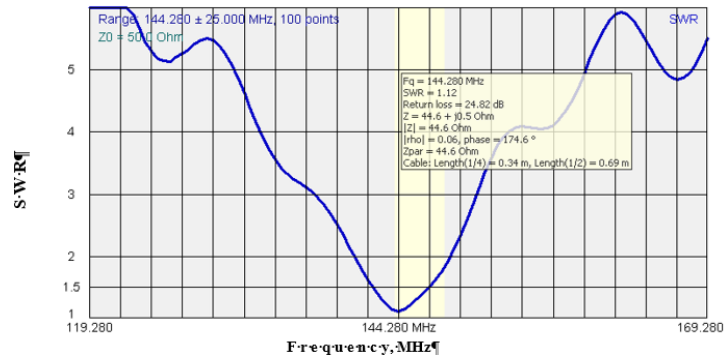

Figure 10. Frequency characteristics of SLC on 2nd antenna

In manually calculation, on antenna impedance to determine the values of the reflection coefficient and its SWR value using (2)-(4) as follows:

$$Z = 44,6 + j0.5 \ \Omega$$

$$|Z| = \sqrt{44,6^2 + 0,5^2} = \sqrt{1989,16 + 0,25} = \sqrt{1989,41} = 44,6028 \ \Omega$$

$$\Gamma = \frac{V_0^-}{V_0^+} = \frac{Z_1 - Z_0}{Z_1 + Z_0} = \frac{50 - 44,6028}{50 + 44,6028} = \frac{5,3972}{94.6028} = 0,057050117$$

$$SWR = \frac{V|max\ |}{V|min\ |} = \frac{1 + \Gamma}{1 - \Gamma} = \frac{1 + 0,057050117}{1 - 0,0570501171} = \frac{1,05705117}{0,94294883} = 1,12100587$$

$$RL = -20 \ log|\Gamma| = -20 \ log \ 0,057050117 = -20 * (-1,24375444) = 25,763044 \ dB$$

whenever compared to manual calculation, the difference is almost zero, so it can be verified that the results of field measurements and calculations are the same manual. Figure 11 has shown the lower frequency limit of the 2nd SLC antenna, which is the SWR value=1:1.47 shown at the frequency of 142,280 MHz, while Figure 12 shows the upper frequency of 146,780 MHz at the SWR value=1:1.51. From both these frequencies can be calculated frequency field width (BW) as the frequency response characteristics of the antenna 2 and also the value of the quality factor. Based on (5), it is obtained:
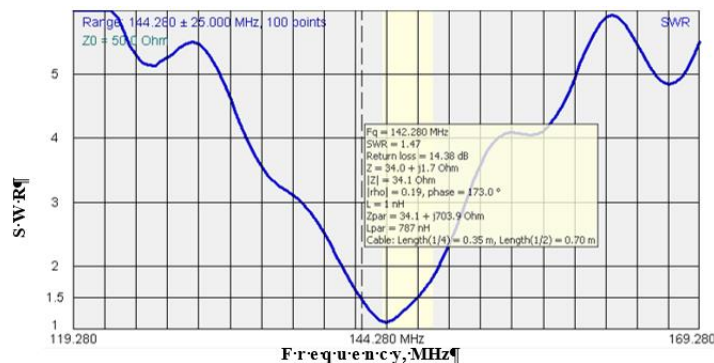
$$BW = 146,780 - 142,280 = 4,500 \ MHz$$

Figure 11. The lower limit frequency of the 2nd antenna

by using (7) the value of the quality factor Q is calculated as follows:

$$Q = \frac{f_o}{BW} = \frac{144,280 \; MHz}{4,500 \; MHz} = 32,062$$
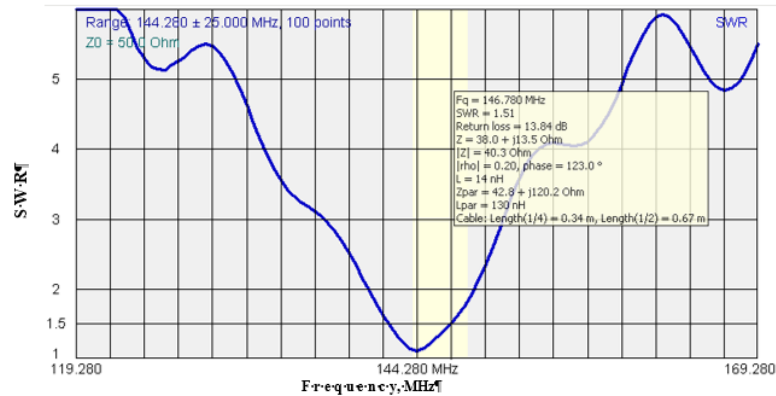

Figure 12. The upper limit frequency of the 2nd antenna

From the data and calculations above, it can be concluded that for the frequency characteristics with a center frequency of 144.280 MHz for 1st antenna CLC the field width is obtained BW=5.166 MHz and the quality factor Q=27.929 while for 2nd antenna SLC the field width is obtained BW=4.500 MHz and quality factor Q=32.062. Thus, it can be said that an antenna with a loading coil made of silver SLC has a higher quality factor or has a higher selectivity than an antenna with a CLC.

5.3. Measurement of antenna gain

For the measurement of the gain or ERP antenna substantially carried out in the open that is in position latitude=0750.66993 S, longitude=11021.76536 E, altitude=90 meters (backyard rest area Pyramid road Parangtritis km 5.5 Yogyakarta) and with 4 different measuring point stations. Each location measurements that Station A is located at a distance of 37 meters with altitude=90 meters (still in around rest area Pyramid), station B at a distance of 23.953 km with altitude=592 meters (in Kaliurang), station C at a distance of 9.507 km with altitude=36 meters (in the town of Bantul) and D stations with a distance of 11.055 km with altitude=100 meters (at Godean). The measurement results are shown in Table 2 as follows:

Table 2. Performance measurement results of the drive test of CLC and SLC

No	Parameters	1st Antenna CLC	2nd Antenna SLC	Impacts
1.	Results Antenna ERP (dbm)	-64.33	-45.35	SLC is bigger than ERP
2.	Results Antenna Gain (dbcollinear)	10.65	29.63	SLC has higher Gain
3.	Sta. A(PD=037km, Alt=90m) signal (dbm)	-68.93	-68.13	SLC greater its radiation emission power
4.	Sta. B(PD=023.953km, Alt=592m) signal (dbm)	-67.02	-45.38	SLC greater its radiation emission power
5.	Sta. C(PD=9.507km, Alt=36m) signal (dbm)	-92.45	-91.93	SLC greater its radiation emission power
6.	Sta. D(PD=11.055km, Alt=100m) signal (dbm)	-73.75	-74.73	SLC greater its radiation emission power

From the results of the ERP measurements above, the total value and gain value of each antenna can be calculated, so that it can show the difference in antenna quality with different loading coil materials. Values of electromagnetic waves received by each antenna location for the measurement point 1 SLC as follows:

$$Station \; A, S1 = antilog - 68.93/10 = 1.279381304x10 - 7mW$$

$Station\ B, S2 = antilog - 67.02/10 = 1.986094917x10 - 7mW$

$Station\ C, S3 = antilog - 92.45/10 = 5.688529308x10 - 10mW$

$Station\ D, S4 = antilogue - 73.75/10 = 4.216965034x10 - 8mW$

the total power received by the 4 points measurement locations in mW as follows:

$$Total\ Power = (1,279381304x10 - 7 + 1,986094917x10 - 7 + 5,688529308x10 - 10$$
$$+ 4,216965034x10 - 8)\ mW$$
$$= (1.279,381304 + 1.986,094917 + 5,688529308 + 421,6965034)x10 - 10\ mW$$
$$= 3,692861254x10 - 7\ mW$$

in the form of logarithms as follows:

$$10\ log\ 3,692861254x10 - 7 = -64,32637\ dBm$$

the amount of ERP for antenna 1 CLC is -64.33 dBm. So that the gain antenna 1 CLC can be calculated -64.33 dBm-(-74.98 dBm)=10.65 dBm, where-74.98 dBm is the total losses in the system.

For Figure 12, the value of the received electromagnetic waves each measurement point location for the 2nd antenna SLC as follows:

$$Station\ A, S1 = antilog - 61,93/10 = 1,53815464x10 - 7mW$$

$$Station\ B, S2 = antilog - \frac{45,38}{10} = 2,897343588x10 - 5mW$$

$$Station\ C, S3 = antilog - \frac{91,93}{10} = 6,412095766x10 - 10mW$$

$$Station\ D, S4 = antilog - 74,73/10 = 3,365115694x10 - 8mW$$

the total power received by the 4 points measurement locations in mW as follows:

$$Power\ Total = (1,53815464x10 - 7 + 2,897343588x10 - 5 + 6,412095766x10 - 10$$
$$+ 336,5115694x10 - 8)mW$$
$$= (1.538,15464 + 289.734,3588 + 6,412095766 + 336,5115694)x10 - 10\ mW$$
$$= 291.615,4371x10 - 10 = 2,916154371x10 - 5mW$$

in the form of logarithms as follows:

$$10\ log\ 2,916154371x10 - 5 = -45,3518949\ dBm$$

the amount of ERP for antenna 2 (SLC) is -45.35 dBm. So that the gain of antenna 2 can be calculated -45.35 dBm - (-74.98 dBm) = 29.63 dBm.

Table 3. Gain measurement results

Measurement location	CLC Antena 1 (dBm)	SLC Antena 2 (dBm)
Station A	-68,93	-68,13
Station B	-67,02	-45,38
Station C	-92,45	-91,93
Station D	-73,75	-74,73
Total ERP	-64,33	-45,35
Gain	10,65	29,63

Measurements in Table 1, Table 2 and Table 3 shows the results in four stations, three of them acquire a greater value for the antenna model 2 SLC so that the overall amount of strong wave field electromagnetic

received by the four stations in the location of the measurement value is greater for antenna 2 based on SLC. So that the antenna model 2 SLC has greater efficiency and gain than the antenna model 1 CLC because it can reduce attenuation and reduce resonance in the telex model antenna.

6. CONCLUSION

From the measurement experiment data, calculation and analysis of the above can be taken some conclusions as follows: a) The length of the feeder cable used in the antenna system must be tuned at the frequency used in order for resonance to occur, so that the impedance of the cable is resistive or the reactive component is minimized. In this study, the cable length according to $1/2\lambda$ was 0.69m and the total cable length was 10.24 meters. b) Characteristics of 144.280 MHz center frequency for antenna model 1 CLC acquired bandwidth BW=5.166 MHz and a quality factor Q=27.929 while the second antenna models SLC was obtained bandwidth BW=4.500 MHz and a quality factor Q=32.062. Thus, an antenna with loading coils of silver material has a higher quality factor or having a higher selectivity compared to an antenna with loading coils of copper. And c) The results of the field strength measurement at 4 measurement stations show that 3 of them obtained a greater value for antenna model 2 SLC so that the overall number of electromagnetic wave field strengths received by the four measurement locations is greater for antenna model 2 SLC. Antenna model 2 SLC also has a greater efficiency and gain of 29.63 dBm than the antenna model 1 SLC) which only has a gain of 10.65 dBm because it can convert electrical energy into greater electromagnetic wave energy by reducing attenuation and reducing resonance on the antenna.

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